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CONTAMINANT EMISSIONS *from the Combustion of Fuels*

ROBERT L. CHASS, Director of Engineering, and **RALPH E. GEORGE,**
Senior Engineer, Los Angeles County Air Pollution Control District

The many attractive features of Southern California living have led to a steady influx of people from other areas. In Los Angeles County, this migration is unprecedented. Since 1940, the population has grown from 2¾ million to over 5½ million people in 1959. Impressive as this increase in population has been, the expansion of commercial and industrial enterprise has been even more dramatic. Keeping pace with this remarkable growth in economic activity has been the growth in demand for thermal energy and in the use of fuels to supply this demand.

By 1980, assuming no restrictions were placed on the burning of fuel oil, community activities in Los Angeles County would require nearly a half million barrels of liquid fuels, exclusive of gasoline, and over 2½ billion cubic feet of gaseous fuels daily. The combustion of these fuels would result in the daily emissions to the atmosphere of 2590 tons of sulfur dioxide, 1350 tons of oxides of nitrogen, and 230 tons of combustion contaminants. This would represent a 455 per cent increase in the emissions of air contaminants over those emitted in 1955 from the combustion of these fuels. Table I shows the expected increase in fuel requirements and resulting emissions to the atmosphere from 1955 to 1980. The amount of fuel oil usage which may be supplanted by natural gas because of Rule 62 limiting the sulfur content of liquid fuels to 0.3 per cent by weight, has not been projected in these estimates.

Table II gives some indication of the tremendous growth of Los Angeles County. By 1980, it is expected that the population will reach 9,980,000 and that there will be 6,350,000 registered vehicles in the County, consuming 11,780,000 gallons of gasoline each day. It is apparent from these figures that considerable planning must be accomplished to prevent these exorbitant tonnages of air contaminants from being released into the atmosphere. It is essential that this area be supplied with the cleanest possible fuel—natural gas. As a step to bring this about, the Air Pollution Control Board promulgated, on November 13, 1958, Rule 62 which, in effect, prohibits the use of any liquid fuel containing sulfur compounds in excess of 0.5 per cent by weight during the calendar period of May 1 through October 31. The rule was designed to compel the use of natural gas in Los Angeles County by steam power plants, oil refineries and other industrial and commercial establishments during the summer and early fall months. It is during these periods that meteorological conditions normally are most conducive to the elevation of atmospheric contaminant concentrations.

It has been recognized that weather conditions favorable to the accumulation of air pollution can also occur during the portions of the year when Rule 62 is not in effect. In order to minimize the emission of contaminants from the combustion of fuel oil on such days, a co-operative voluntary program known as "Operation Fuel Switch" has been entered into by consumers of large quantities of fuel oil.

Operation Fuel Switch was initially instituted at the urging of the Air Pollution Control Officer during the fall of 1957 and continued in an experimental fashion until January 2, 1959. At this time, there was initiated an expanded detailed program involving those consumers who, in the aggregate, account for 80 per cent of the fuel oil used in Los Angeles County.

This program involves the following detailed plan of action:

1. Oil refineries, power plants and other large industrial fuel users voluntarily cease the burning of fuel oil on those days when the APCD requests that Operation Fuel Switch be placed into action because of expected moderate-to-heavy eye irritation.
2. APCD meteorologists notify the local gas co-ordinator of expected smog conditions by means of forecasts issued three times daily—10 A.M. (forecast for the following day), 3 P.M. (forecast for the following day), and 8 A.M. (forecast for the same day).
3. The APCD notifies the oil refineries, power plants and other large industrial fuel users, by means of selective calling facilities, daily at 2 P.M., of the expected air pollution conditions.
4. In the event that the 8 A.M. smog forecast indicates that the two previous forecasts are no longer valid, due to a rapid change in weather conditions, the APCD will inform the local gas co-ordinator, as well as the large users of fuel oil, to that effect at approximately 8 A.M.

It is not within the scope of this paper to present an evaluation of the effects of

Table I—Forecast of Fuel Requirements of Los Angeles County and Resulting Emissions to the Atmosphere

	Fuel Requirements[a]				Emissions to the Atmosphere		
Year	Residual Fuel Oil, Bbls/Day	Distillate Fuel, Bbls/Day	Natural Gas, Bbls/Day[b]	Refinery Gas, Bbls/Day[b]	Sulfur Dioxide, Tons/Day	Oxides of Nitrogen, Tons/Day	Combustion Contaminants, Tons/Day
1955	60,000	5,000	155,000	35,000	420	275	40
1960	80,000	7,000	190,000	45,000	510	360	50
1970	225,000	15,000	285,000	50,000	1,275	750	125
1980	450,000	20,000	380,000	50,000	2,500	1,350	230

[a] R. S. Tulin, Fuel Requirement and Supply—Liquid Petroleum and Natural Gas, District V—Los Angeles Basin, Report of Joint Research Council, Jan. 1958.
[b] Six thousand cubic feet of natural gas or refinery gas is considered equivalent to one barrel of fuel oil.

[*] Presented at the 52nd Annual Meeting of APCA, June 21–26, 1959, Statler Hotel, Los Angeles, Calif.

peration Fuel Switch but rather to ow that the emission of air contaminants from the burning of fuel oil is one f the three remaining major air pollution problems facing control officials Los Angeles County. It is hoped hat sufficient supplies of natural gas ill be made available in the near future enable Rule 62 to be made applicable e year round. Operation Fuel Switch the meantime will implement Rule 2 during the so-called winter season.

In view of the enormous tonnages of r contaminants emitted into the atosphere from the burning of fuel oil, a rogram was designed to determine ission factors for all types of comustion sources utilizing both liquid and aseous fuels. This paper presents the sults to date of this combustion study.

Consumption of Gaseous and Liquid Fuels in Los Angeles County

The emissions of air contaminants rom the burning of fuel oil present a erious air pollution problem in Los ngeles County. Recognition of this act has created the impetus necessary o acquire the knowledge and understanding of the problem required for its olution. In investigating this problem, an assessment was made of the uture demands for thermal energy in iew of the vigorous growth in population and industry and the extent to which fuel oil and natural gas respectively had supplied these requirements in the past and would supply them in the uture.

Most industrial plants and steam-electric generating power plants in Los Angeles County are equipped to burn both fuel oil and natural gas. Practically all commercial and small industrial establishments, as well as the majority of large industrial establishments, normally burn natural gas with oil used only as a standby fuel. Natural gas is the preferred fuel generally, as it provides thermal energy at the lowest cost per BTU, but the extent to which it is used in lieu of fuel oil is almost entirely dependent upon the availability of natural gas supplies. The majority of large industrial plants receive natural gas on an interruptible basis and, as a result, are not adequately supplied during periods of heavy total demand. Essentially, all of the demand for thermal energy in Los Angeles County is being met with petroleum and natural gas fuels. When gas is not available to meet the demand, the energy deficit is normally filled by residual fuel oil.

In determining the over-all energy requirements of this area and the fuel demand for the future, it was necessary to examine expected population growth and expansion of commercial and industrial activity. Historical data were developed on the demand for liquid and gaseous fuels for the period from 1954 through 1958.

The industrial fuel requirements of this area are met in quite a different manner from that of the rest of the country. Together, oil and natural gas supply essentially 100 per cent of the fuel requirements in Los Angeles County. For the past five years, fuel oil has supplied from 30 to 35 per cent of the area's industrial fuel require-

Table II—Growth of Los Angeles County

Year	Population	Registered Vehicles	Gasoline Consumption, Gals/Day	Industries
1940	2,785,643	1,220,361	1,920,000	5,900
1950	4,151,687	2,007,552	3,850,000	11,500
1960	6,120,000	3,450,000	6,400,000	17,000
1970	8,050,000	4,900,000	9,100,000	21,000
1980	9,980,000	6,350,000	11,780,000	25,000

Table III—Fuel Oil and Natural Gas Usage by Power Plants, Oil Refineries and Other Interruptible Industrial Sources in Los Angeles County and Gas Supply Potentially Available for 1954 Through 1958

	Expressed as Equivalent Barrels of Fuel Oil[a]			
Year	Fuel Oil Burned	Natural Gas Burned	Natural Gas Available	Natural Gas Available But Not Purchased
1954	15,308,031	25,722,215	29,085,145	3,362,930
1955	20,048,128	24,089,892	24,518,359	428,467
1956	19,665,748	26,362,888	26,575,538	212,650
1957	22,280,017	27,747,525	27,747,525	...
1958	16,562,733	28,082,778	34,481,978	6,399,200

[a] Six thousand cubic feet of natural gas is considered equivalent to one barrel of fuel oil.

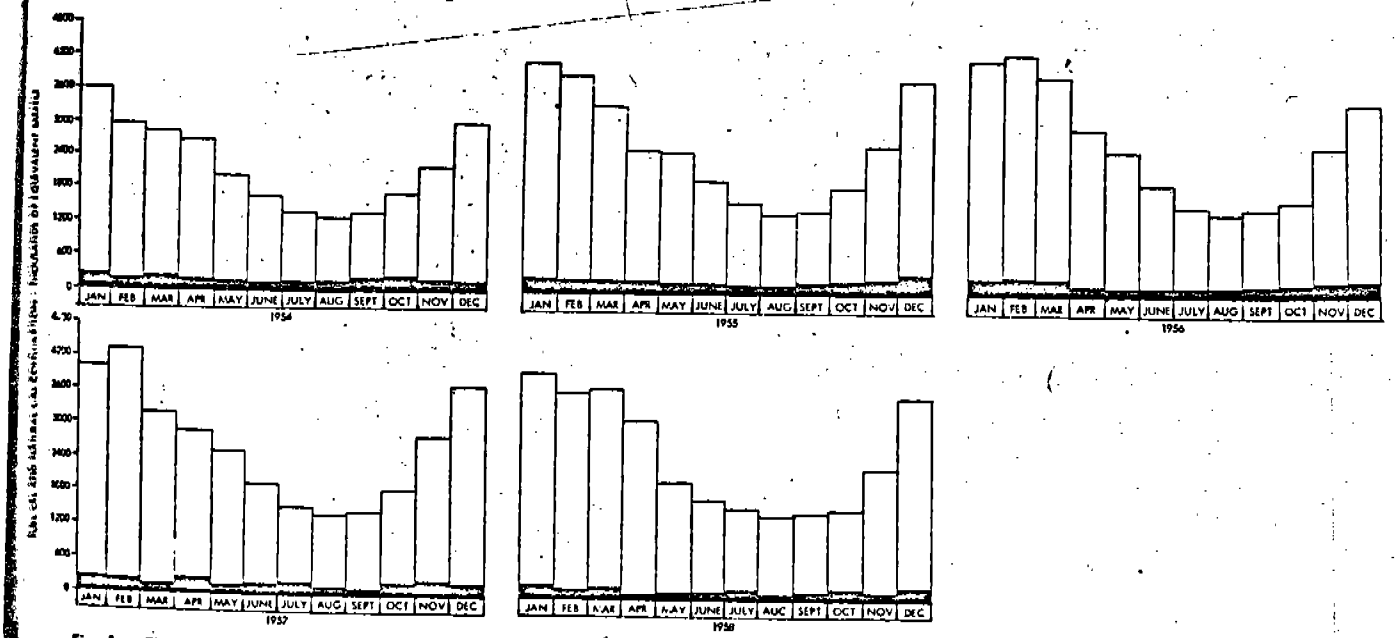

Fig. 1. Five-year summary of monthly fuel oil and natural gas consumption by general service (firm gas) gas customers in Los Angeles County for 1954 through 1958.

Table IV—Five Year Summary of Fuel Oil and Natural Gas Usage and Percentage of Total Fuel Oil and Natural Gas Burned by General Service and Industrial Gas Customers in Los Angeles County for 1954 Through 1958

	Fuel Usage Expressed as Equivalent Barrels of Fuel Oil									General Service		Industrial Sources	
	General Service (Firm Gas Users)[a]			Industrial Sources (Interruptible Gas Users)[b]			Total Fuel Use, All Sources			Oil % of Total Fuel Oil	Gas % of Total Natural Gas	Oil % of Total Fuel Oil	Gas % of Total Natura Gas
Year	Fuel Oil	Natural Gas	Total Fuel Oil	Fuel Oil	Natural Gas	Total Fuel Oil	Fuel Oil	Natural Gas	Grand Total				
1954	2,104,406	24,401,241	26,505,647	15,308,031	25,722,215	41,030,246	17,412,437	50,123,456	67,535,893	12.1	48.7	87.9	51.3
1955	2,639,855	28,246,574	30,886,429	20,048,128	24,089,892	44,138,020	22,687,983	52,336,466	75,024,449	11.6	54.0	88.4	46.0
1956	2,583,207	29,295,600	31,878,807	19,665,748	26,362,888	46,028,636	22,248,955	55,658,488	77,907,443	11.6	52.6	88.4	47.4
1957	2,345,239	29,293,676	31,638,915	22,280,017	27,747,525	50,027,542	24,625,256	57,041,201	81,666,457	9.5	51.4	90.5	48.6
1958	1,904,773	28,671,648	30,576,421	16,562,733	28,082,778	44,645,511	18,467,506	56,754,426	75,221,932	10.3	50.5	89.7	49.5

[a] Includes all domestic, commercial and industrial sources on firm gas schedules.
[b] Includes power plants, oil refineries and all other industrial sources on interruptible gas schedules.

ments, with natural gas and refinery-produced fuel gas supplying the balance.

Data are presented in Tables III through VII and Fig. 1 through 11 on fuel usage by nearly every segment of the domestic, commercial and industrial complex of Los Angeles County. Included in the category of "interruptible industrial sources," are the power plants, oil refineries and other large industrial sources purchasing natural gas on curtailable schedules. The "general service" category includes all domestic, commercial and small industrial users of natural gas, purchasing gas on firm or noncurtailable schedules.

In Table III, historical data are given on the total amount of fuel oil and natural gas consumed by power plants, oil refineries and other large industrial sources in Los Angeles County for the period 1954 through 1958. Also shown are data on the quantities of natural gas which were available to consumers in this area from out-of-state sources, but were not purchased. Fig. 1 through 4 provide a monthly breakdown of oil and natural gas consumption in Los Angeles County for this same five-year period, by general service gas customers, interruptible industrial customers (large industrial sources other than power plants and oil refineries), oil refineries and power plants respectively.

Table IV presents a comparison of fuel usage by general service and industrial gas customers in Los Angeles County for the years 1954 through 1958.

Total yearly fuel usage, as well as a breakdown of the quantities and percentages of each fuel burned by power plants, oil refineries and other interruptible industrial sources in Los Angeles County, is tabulated in Table V.

In Table VI, a monthly breakdown is given of the quantities of fuel oil and natural gas burned in Los Angeles County in 1958 by power plants, oil refineries and other interruptible industrial sources. Also shown is the natural gas supply potentially available for each month of this period and the quantities of natural gas which were available but not purchased during this same period.

Table VII presents an estimate of the total potential fuel requirements of all firm and interruptible gas customers in Los Angeles County (including portions of adjacent counties in the same gas service area) and the potential supply of natural gas projected for the calendar period of May 1–October 31, 1959, through 1965 (effective period of Rule 62).

In projecting the fuel requirements of Los Angeles County no attempt was made to establish how these requirements would be met, except during the period when Rule 62 would be in effect. It is apparent from the forecast of potential fuel requirements that substantial quantities of both fuel oil and natural gas will be needed to meet the estimated demand during the 1959–1970 period. It is expected that the indigenous production of natural gas will not be adequate and gas suppliers will need to rely to an ever increasing degree upon out-of-state supplies.[1] To the increased deliverability already programmed by the natural gas suppliers, even greater expansion will take place within the next ten years. If present contractual agreements of the gas companies for out-of-state gas are approved by all the regulatory bodies, Los Angeles

Table V—Total Yearly Fuel Usage and Percentage of Yearly Fuel Requirements Supplied by Fuel Oil at Power Plants, Oil Refineries and Other Interruptible Industrial Sources in the Los Angeles Basin for 1954 Through 1958

Industrial Source	Type of Fuel	Amount of Fuel Burned Expressed in Equivalent Barrels of Oil[a] 1954	1955	1956	1957	1958
Power plants	Fuel oil	5,012,510	11,111,785	11,417,635	14,557,322	7,414,082
	Natural gas	11,578,750	9,987,889	10,058,395	11,178,402	14,529,994
	Subtotal	16,591,260	21,099,674	21,476,030	25,735,724	21,944,076
	Oil per cent of total fuel use	30.2	52.7	53.2	56.6	33.8
Oil refineries	Fuel Oil	3,098,085	2,089,631	1,420,071	1,248,642	3,362,951
	Natural gas	6,124,863	7,290,136	8,609,156	8,866,155	5,508,158
	Refinery make gas	10,053,214	10,851,685	11,659,611	11,962,624	14,263,276
	Subtotal	19,276,162	20,231,452	21,688,838	22,077,421	23,134,385
	Oil per cent of total fuel use	16.1	10.3	6.5	5.7	14.5
Other industrial	Fuel oil	7,197,436	6,846,712	6,828,042	6,474,053	5,785,700
	Natural gas	8,018,602	6,811,867	7,695,337	7,702,968	8,044,626
	Subtotal	15,216,038	13,658,579	14,523,379	14,177,021	13,830,326
	Oil per cent of total fuel use	47.3	50.1	47.0	45.7	41.8
Total yearly fuel oil usage		15,308,031	20,048,128	19,665,748	22,280,017	16,562,733
Total yearly natural gas usage		25,722,215	24,089,892	26,362,888	27,747,525	28,082,778
Total yearly refinery make gas usage		10,053,214	10,851,685	11,659,611	11,962,624	14,263,276
Grand total yearly fuel usage		51,083,460	54,989,705	57,688,247	61,990,166	58,908,787
Oil per cent of total fuel use		30.0	36.5	34.1	35.9	28.1

[a] Six thousand cubic feet of natural gas is considered equivalent to one barrel of fuel oil.

County will be assured of a natural gas supply sufficient to meet its total potential fuel requirements for the next six years, at least during the six months' period when Rule 62 is in effect.

Emissions from Combustion Sources

Investigations in the control of air pollution from the combustion of fuels was intensified early in 1954 when it was found that in utilizing heavy fuel oils large steam-electric generating installations could not be operated without visible stack emissions or so-called plumes in violation of the Rules and Regulations of the Air Pollution Control District.

A great deal of progress has since been made in the relatively unstudied field of power plant air pollution control through the co-operative efforts of the power generating agencies and the APCD. Research efforts in this direction have been co-ordinated by a Joint Research Council on Power Plant Air Pollution Control, formed in March 1956.

The power plant plume phenomenon is still not fully understood, but it is generally agreed that plume opacity is affected significantly by particulate matter, by the small amount of SO_3 present in the stack effluent, as well as the water vapor present; by ambient atmospheric conditions, by the angle of illumination, and by the kind of background against which the plume is observed.[2]

From the available stack test data on power plants, an evaluation was made of the contribution of this source to air pollution. Table VIII shows the effects of population and industrial growth in Los Angeles County on steam-electric power production projected to 1970. Also shown are the fuel requirements and a comparison of contaminant emissions from the burning of fuel oil and the natural gas equivalent of fuel oil.

In 1959, the total annual power requirement is estimated at 24 billion kilowatts. Of this total, approximately 15 to 16 billion kilowatts, or 65 per cent, will be supplied by steam generating power plants within the County. If all of these plants were to burn fuel oil exclusively with an average sulfur content of 1.5 per cent, the resultant emissions would be 320 tons per day of sulfur dioxide, 185 tons of oxides of nitrogen and 30 tons of combustion contaminants. If natural gas were burned exclusively, such emissions would be reduced to 0.1 ton per day of sulfur dioxide, 120 tons of oxides of nitrogen and 3 tons of combustion contaminants.

Table VI—Fuel Oil and Natural Gas Burned in Los Angeles County in 1958 by Power Plants, Oil Refineries and Other Interruptible Industrial Sources and Natural Gas Supply Potentially Available

Month	Expressed as Equivalent Barrels of Fuel Oil[a]: Fuel Oil Burned	Natural Gas Burned	Natural Gas Available	Natural Gas Available But Not Purchased[b]
Jan.	1,753,633	2,009,795	2,030,212	20,417
Feb.	1,254,064	2,358,481	2,383,881	25,400
Mar.	1,501,254	2,014,588	2,015,671	1,083
Apr.	1,202,338	1,886,987	2,516,487	629,500
May	955,591	2,447,140	3,214,640	767,500
Jun.	1,110,967	2,572,725	3,429,492	856,767
Jul.	1,204,291	2,459,144	3,468,544	1,009,400
Aug.	1,490,374	2,517,193	3,637,443	1,120,250
Sep.	1,265,994	2,755,359	3,557,542	802,183
Oct.	1,309,164	2,672,581	3,389,848	717,267
Nov.	1,745,366	2,103,385	2,435,118	331,733
Dec.	1,769,697	2,285,400	2,403,100	117,700
Totals	16,562,733	28,082,778	34,481,978	6,399,200

[a] Six thousand cubic feet of natural gas is considered equivalent to one barrel of fuel oil.
[b] Estimated out-of-state supply.

Table VII—Potential Fuel Requirements of All Firm and Interruptible Gas Customers and Potential Supply of Natural Gas Projected for the Calendar Period May 1– October 31, 1959, Through 1965[a]

Year	Millions of Cubic Feet Per Day: Potential Requirements[b]	Potential Supply	Expected Surplus
1959	1,680.6	1,680.6	0
1960	1,927.6	2,086.3	158.7
1961	2,017.5	2,178.7	161.2
1962	2,118.2	2,275.4	157.2
1963	2,185.0	2,272.6	87.6
1964	2,303.0	2,400.1	97.1
1965	2,443.1	2,482.3	39.2

[a] Forecast estimates by Pacific Lighting Gas Supply Company.
[b] Refinery make gas not included.

Although the oil refineries in Los Angeles County burn only a third as much fuel oil as the power plants, their combined fuel usage, including refinery make gas, is greater than the total fuel usage by power plants. In August 1955, a study was initiated to determine the extent of the emissions from combustion sources in oil refineries.[3]

The total annual consumption of fuel oil, natural gas and refinery make gas by the oil refineries in 1958 amounted to over 23 million equivalent barrels or an

Table VIII—Effects of Population and Industrial Growth in Los Angeles County on Steam-Electric Power Production and Fuel Requirements and Comparison of Contaminant Emissions from the Burning of Fuel Oil and Natural Gas Equivalent of Fuel Oil[a]

Year	Population (Millions)	Total Power Requirement (Billion Kilowatt-Hours per Year)	Steam-Electric Power Production (Billion Kilowatt-Hours per Year)	Fuel Required for Power Production (Thousand Equivalent Barrels per Day)	Sulfur Dioxide Emissions from Fuel Oil (Tons per Day)	Sulfur Dioxide Emissions from Natural Gas (Tons per Day)	Nitrogen Oxide Emissions from Fuel Oil (Tons per Day)	Nitrogen Oxide Emissions from Natural Gas (Tons per Day)	Aerosol Emissions from Fuel Oil (Tons per Day)	Aerosol Emissions from Natural Gas (Tons per Day)
1950	4.2	8	4.5	20	105	0.02	60	40	10	1
1958	5.6	24	15	60	320	0.1	185	120	30	3
1970	8	66	43	190	1020	0.2	570	380	95	10

[a] Los Angeles County Air Pollution Control District Fuel Survey; R. S. Tulin, Fuel Requirement and Supply—Liquid Petroleum and Natural Gas, District V—Los Angeles Basin; Twenty-Eighth Annual Report—Utilities—Los Angeles Area, 1957–1958 Los Angeles Chamber of Commerce.

Table IX—Description of Equipment Tested

Reference No.	Equipment	Type	Burner Data — Gas — Mfg.	Gas — Type	Gas — Pressure, Psig	Oil — Mfg.	Oil — Type	Oil — Pressure, Psig	Oil — Temp., °F	Draft	Combustion Controls — Gas	Combustion Controls — Oil	Steam Pressure, Psig	Fuels Burned — Gas	Fuels Burned — Oil	Test No.
1	Thompson Tubeless Boiler—30 hp	Tubeless	Thompson	Premix Aspirator	0.3	—	—	—	—	Natural	Automatic	—	15	Natural	—	C-526
2	Cyclotherm Steam Generator—60 hp	Fire-Tube	Cyclotherm	Nozzle Mix	0.3	Cyclotherm	Pressure Atomizing	150	70	Natural	Automatic	Automatic	70	Natural	PS200	C-494
3	Bryan No. 315—100 hp	Water Tube	—	—	—	Johnson BH-2A	Pressure Atomizing	115	70	Natural	—	Automatic	Hot Water	—	PS200	C-509
4	Locomotive Type Boiler—120 hp	Single-Pass Fire-Tube	—	—	—	N.A.	Steam Atomizing	N.A.	160	Natural	—	Manual	100	—	PS300	C-456
5	Pioneer Boiler—125 hp	Scotch Marine	—	—	—	N.A.	Pressure Atomizing	52	70	Natural	—	Automatic Off-On	90	—	PS300	C-493
6	Dixon Water Wall Boiler—125 hp	Scotch Marine	Nemec	Multi-Jet Ring Type	0.3	—	—	—	—	Natural	Automatic Modulating	—	100	Natural	—	C-451
7	Dixon Water Wall Boiler—150 hp	Scotch Marine	Nemec	Multi-Jet Ring Type	0.3	Nemec	Steam Atomizing	N.A.	70	Natural	Automatic Modulating	Semi-Automatic	100	Natural	PS200	C-450
8	Gabriel Boiler—150 hp	Scotch Marine	Johnson 150	Multi-Jet Ring Type	0.3	Johnson 150	Centrifugal Atomizing	140	70	Natural	Automatic Modulating	Automatic Off-On	10	Natural	Diesel	C-454
9	Johnston Boiler No. 18—200 hp	Scotch Marine	Johnston	Multi-Jet Ring Type	0.3	Johnston Rotary	Centrifugal Atomizing	N.A.	70	Natural	Automatic	Automatic	90	Natural	Diesel	C-455
10	B & W Boiler Model FM-27—200 hp	Water-Tube	Todd	Multi-Jet Ring Type	0.3	Todd	Pressure Atomizing	25	70	Natural	Automatic	Automatic	120	Natural	Diesel	C-527
11	Erie City Boiler Model 4C-14—245 hp	Water-Tube 3-Drum	Leahy	MCL 7-23 4-Segment	9	Leahy	MCL 7-23	85	205	Induced	Automatic Modulating	Semi-Automatic	120	Natural	PS400	C-596
12	B & W Boiler Type FM-1—300 hp	Water-Tube	Todd Roto-Press	Ring Type	3.5	Todd Roto-Press	Centrifugal Atomizing	7.5	70	Natural	Automatic	Automatic	600	Natural	PS200	C-595
13	Kewanee Boiler Model 590—300 hp	Modified HRT 2 Pass-Fire-Tube	Martois	A-27-6 Multi-Jet	3.5	Leahy	Steam Atomizing	100	60	Induced	Automatic Modulating	Semi-Automatic	100	Natural	PS200	C-591
14	Dixon Wet Back Boiler—350 hp	Scotch Marine	Enterprise	Multi-Jet Ring Type	0.3	Enterprise	Centrifugal Atomizing	N.A.	70	Induced	Automatic Modulating	Automatic Modulating	150	Natural	Diesel	C-525
15	Collins Boiler—425 hp	Water-Tube	Lientz No. 611-A	Multi-Jet Nozzle Mix	0.5	Lientz No. 611-A	Steam Atomizing	40	210	Natural	Automatic	Automatic	160	Natural	PS400	C-452
16	Springfield Boiler—460 hp	Water-Tube	Peabody	Multi-Jet Ring Type	3.0	Peabody	Pressure Atomizing	200	170	Induced	Automatic Modulating	Automatic Modulating	275	Natural	PS300	C-593
17	Sterling Boiler Model 477-31 (Modified)—500 hp	Water-Tube 4-Drum	Nemec	Multi-Jet Nozzle Mix	7.0	Nemec	Steam Atomizing	65	160	Induced	Automatic Modulating	Semi-Automatic	145	Natural	PS300	C-592
18	Collins Boiler—580 hp	Water-Tube	Nemec	Multi-Jet Ring Type	0.3	Nemec	Steam Atomizing	45	160	Natural	Automatic	Automatic	15	Natural	PS300	C-443
19	B & W Boiler Model FM-9—870 hp	Water-Tube	B & W	Multi-Jet Ring Type	2.3	B & W Y-Jet	Steam Atomizing	58	220	Natural	Automatic	Automatic Modulating	275	Natural	PS400	C-459
20	General Water Heater Corp. Model A-75 H	75 Gallon Hot Water Heater	General	Premix Multi-Jet	0.3	—	—	—	—	Natural	Automatic Off-On	—	—	Natural	—	C-446
21	Utility Appliance Corp. Model 125 UF Space Heater	100,000 Btu/hr. Forced Air Heater	Utility	Premix Inspirator	0.3	—	—	—	—	Natural	Automatic Off-On	—	—	Natural	—	C-447
22	Vensel Bonderizing Oven	Indirect Fired	N.G.E.	3" Premix Aspirator	0.3	—	—	—	—	Natural	Semi-Automatic	—	—	Natural	—	C-507
23	Vensel Paint Bake Oven	Indirect Fired	Eclipse	2½"-#1462 Premix Aspirator	0.3	—	—	—	—	Natural	Automatic Off-On	—	—	Natural	—	C-506
24	Bake Oven	Indirect Fired	Pacific Gas	Premix Inspirator	0.3	—	—	—	—	Natural	Manual	—	—	Natural	—	C-508
25	425 Pound Crucible Type Aluminum Melting Furnace	Indirect Fired	Custom Made	Premix Aspirator	0.3	—	—	—	—	Natural	Manual	—	—	Natural	—	C-505
26	Childers Oil Heater Model D-100	Oil Circulating Heat Exchanger	—	—	—	Childers	Pressure Atomizing	N.A.	70	Natural	—	Automatic Off-On	—	—	PS200	C-457
27	Prouty Custom Artware Kiln	Indirect Fired Full Muffle	Petro-Fire	Premix Aspirator	0.3	Petro-Fire	Premix Vaporizer	0.5	70	Induced	Automatic Modulating	Automatic Modulating	—	Natural	PS100	C-502
28	Lehr Glassware Decorating Oven	Indirect Fired Full Muffle	Custom Made	Premix Inspirator	1.0	—	—	—	—	Natural	Automatic Modulating	—	—	Natural	—	C-465
29	Ceramic Tunnel Kiln	Indirect Fired	Custom Made	Premix Inspirator	—	—	—	—	—	Natural	Automatic Modulating	—	—	Natural	—	C-463
30	Semi-Muffle Dinnerware Kiln	Indirect Fired	Petro-Fire	Premix Inspirator	0.5	Petro-Fire	Premix Vaporizer	0.5	—	Induced	Automatic	Automatic	—	Natural	Kerosene	C-504

— Does not apply.
N.A.—Not Available.

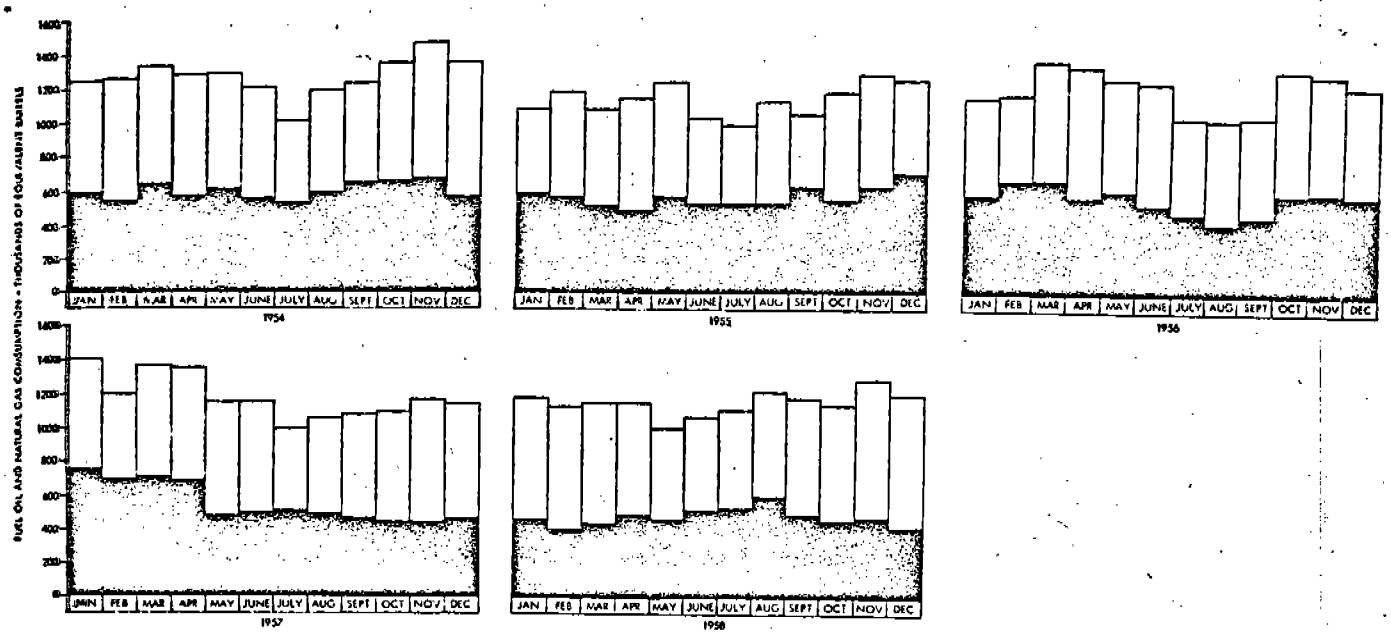

Fig. 2. Five-year summary of monthly fuel oil and natural gas consumption by other industrial (interruptible gas) gas customers in Los Angeles County for 1954 through 1958.

annual daily average fuel usage of over 63 thousand equivalent barrels. The combustion of these fuels by refineries resulted in daily emissions to the atmosphere of 115 tons of sulfur dioxide, 50 tons of nitrogen oxides and 10 tons of combustion contaminants.

APCD Stack Testing Program

The total fuel usage by other interruptible industrial sources approximates only 20 per cent of the combined fuel usage by power plants and oil refineries, but in the consumption of fuel oil it is the second largest source. In view of this, and in the absence of sufficient data to allow an evaluation of the emissions from this category of industrial combustion sources, an investigation and tack testing program was initiated early in 1957. Preliminary planning required the identification of all commercial and industrial processes or operations utilizing combustion equipment. It was necessary also to predetermine that, in a stack test of the equipment selected, it would be possible to sample only the contaminants resulting from the combustion of fuels and to exclude the emissions from any other portion of the integrated process. In selecting the equipment for testing, an attempt was made to include as many different types and sizes of equipment as possible. Aside from these considerations, the units selected for testing were based on accessibility and availability of adequate sampling facilities. Included in addition to the obvious sources, i.e., boilers and heaters, such equipment as driers, ovens and furnaces operating on both oil and gas were tested. Of the 30 units of combustion equipment listed in Table IX, 15 were tested while fired with both gas and oil fuels. Eleven were tested on natural gas firing only, and four were tested on oil firing only, giving a total of 45 stack tests. Over 800 separate analyses were required to determine the emissions of contaminants from the combustion sources tested.

All of the stacks were tested for combustion contaminants,* aldehydes, oxides of nitrogen, sulfur dioxide, sulfur trioxide, hydrocarbons, carbon monox-

* "Combustion Contaminants" are particulate matter discharged into the atmosphere from the burning of any kind of material containing carbon in a free or combined state. (Rule 2m of the Los Angeles County Air Pollution Control District Rules and Regulations.)

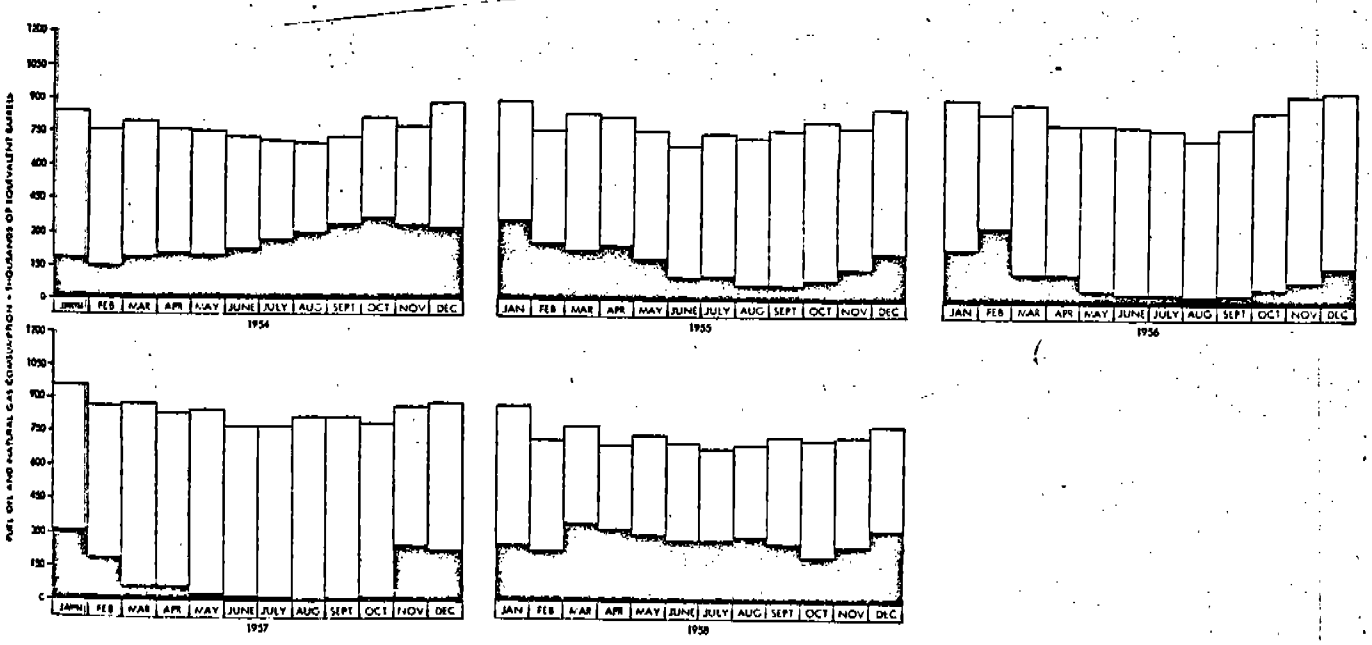

Fig. 3. Five-year summary of monthly fuel oil and natural gas consumption by oil refineries in Los Angeles County for 1954 through 1958.

Table X—Emissions from Gas Fired Combustion Equipment

Reference No.	Natural Gas Burned, SCFH	Flue Gas Data—Stack Conditions: Volume, SCFM[b]	Temp., °F	Orsat Analysis (Wet Basis) CO_2, Vol. %	O_2, Vol. %	CO, Vol. %[c]	Excess Air, Vol. %	Moisture, Vol. %	Air Contaminant Emissions[a]: Combustion Contaminants[d] Grains per SCF	Grains per SCF @ 12% CO_2	Pounds per Hour	Aldehydes (as Formaldehyde) Ppm	Pounds per Hour	Oxides of Nitrogen (As NO_2) Ppm	Pounds per Hour
1	840	400	550	4.8	10.0	0.000	98	9.2	0.0035	0.0088	0.012	3	0.005	33	0.10
2	2,040	720	300	4.5	9.3	0.1	93	14.3	0.019	0.051	0.12	4	0.02	37	0.20
6	6,600	1,200	460	4.2	1.7	6.4	0	15.6	0.035	0.10	0.36	25	0.1	5	0.04
7	7,200	1,800	580	7.4	2.3	0.2	13	18.3	0.0049	0.0079	0.08	2	0.02	28	0.4
8	2,220	2,700	460	1.7	17.2	0.00	28	4.3	0.0004	0.003	0.009	3	0.05	8	0.16
9	4,260	1,700	370	4.8	9.6	0.000	94	10.8	0.0011	0.0028	0.016	4	0.03	13	0.16
10	2,487	1,250	380	3.8	11.3	0.000	135	10.8	0.0017	0.0054	0.018	11	0.065	16.1	0.146
11	14,100	5,000	500	5.4	2.7	4.6	16	14.7	0.0018	0.004	0.077	19	0.45	12.8	0.47
12	4,860	1,200	440	7.8	2.3	0.01	13	16.6	0.0022	0.0034	0.02	3	0.02	38.2	0.334
13	6,120	3,100	330	3.8	12.4	0.000	124	8.2	0.0079	0.0025	0.021	4	0.06	34.8	0.79
14	10,800	4,100	480	5.0	8.2	0.000	72	13.3	0.0013	0.0031	0.046	7	0.14	56	1.7
15	24,600	7,800	600	6.1	6.4	0.02	48	12.9	0.0576	0.113	3.8	53	1.7	111.6	5.50
16	15,420	5,400	218	5.2	9.1	0.0	85	11.2	0.0018	0.004	0.08	4	0.09	39.4	1.55
17	28,800	11,500	600	4.8	9.0	0.0	84	10.9	0.0033	0.0082	0.33	4	0.2	124	10.4
18	11,100	2,400	470	7.0	0.5	1.8	0	18.0	0.00619	0.0106	0.13	3.5	0.033	92	1.3
19	24,000	9,200	480	5.0	8.1	0.02	73	14.6	0.0022	0.0053	0.17	10	0.5	127	8.5
20	117	81	110	3.4	14.6	0.001	203	5.7	0.007	0.03	0.005	2	0.002	45.8	0.026
21	130	124	160	2.0	17.7	0.0	480	3.8	0.001	0.01	0.001	2	0.001	19.0	0.016
22	408	155	373	5.0	9.5	0.000	99	11.6	0.0007	0.002	0.0009	3	0.003	34.1	0.038
23	384	230	370	1.7	16.6	0.000	437	5.0	0.0013	0.009	0.0026	6	0.006	16.0	0.026
24	582	310	250	3.5	14.7	0.000	38	7.0	0.0018	0.062	0.0048	6	0.008	19.5	0.045
25	1,146	1,300	330	18.1	1.0	0.000	6	20.0	0.0069	0.075	0.073	0	0	102	0.16
27	619	240	440	5.6	9.1	0.04	67	5.6	0.002	0.01	0.004	2.2	0.0025	13.4	0.023
28	420	422	360	0.7	19.4	0.0	*	2.9	0.0012	0.021	0.0043	3.9	0.0045	2.8	0.0046
29	1,140	450	1040	4.9	10.0	0.000	105	11.7	0.0021	0.0051	0.0081	5	0.01	66	0.22
30	4,679	1,100	590	2.7	15.7	0.000	355	6.1	0.0051	0.023	0.048	6.7	0.035	18.8	0.15

[a] All concentrations expressed at actual stack conditions except where otherwise noted.
[b] Standard conditions are 60 degrees Fahrenheit and 14.7 PSIA.
[c] All CO measurements below 0.1% were made with M.S.A. instrument.
[d] "Combustion Contaminants" are particulate matter discharged into the atmosphere from the burning of any kind of material containing carbon in a free or combined state. (Rule 2m of the Los Angeles County Air Pollution Control District Rules and Regulations.)
[e] Excess air introduced after combustion zone.

ide, carbon dioxide and oxygen. In the majority of tests the stack gas flow rate was determined directly by Pitot traverse, but where physical limitations or location of the sampling stations did not allow a direct measurement, the flow rate was calculated using stoichiometric principles. The temperature of the stack gases was measured in all cases. Fuel rate and fuel composition were also obtained. In the case of natural gas-fired equipment, the gas composition was assumed as 85 per cent methane, 12 per cent ethane and three per cent inert material, which is the average composition of natural gas burned in this area.

The results of the source testing program are shown in Tables X and XI. It will be noted in Table X, which gives the emissions from gas-fired combustion equipment, that the only contaminants listed are combustion contaminants, aldehydes and oxides of nitrogen. Sulfur dioxide and sulfur trioxide were omitted because they could not be detected or else were found to occur in such extremely low concentrations in the stack they were considered as negligible. Similarly, it will be noted that hydrocarbons were not reported for either gas or oil-fired equipment as the concentrations in which they occurred in every case were below the quantitative range of the analytical technique.

Evaluation of Stack Test Data

Emissions of air contaminants from combustion equipment are dependent not only on the type and composition of fuel burned but on many other variable factors. In selecting equipment for testing, an effort was made to obtain as many variations of combustion parameters and operating conditions as possible. This was done so that the stack test data would reflect an average or representative cross section of industrial combustion sources.

In Tables XII and XIII are shown the emission factors for the combustion sources tested. Emission factors for each of the contaminants were calculated from the test data for both oil-fired and gas-fired equipment in terms of pounds per equivalent barrel of fuel oil.

Emissions of sulfur oxides are a direct function of the fuel composition, while the emissions of other contaminants are influenced by such variables as combustion chamber design, method of combustion-air introduction, combustion temperature, burner design, burner spacing or configuration and other combustion parameters. From the test data obtained, no correlation can yet be found to show the extent to which contaminant emissions will vary as combustion parameters differ. Contrary to popular opinion, the emissions of air contaminants will vary considerably from similar types of equipment and from similar sizes of the same equipment.

The measured values of sulfur dioxide agreed quite well with the values calculated from the fuel analysis. In the oil-fired combustion equipment, nitrogen oxide concentrations varied from a low of 14.7 to a high of 387 parts per million. The results obtained for gas operation varied from a low of 2.8 to a high of 127 parts per million. As expected, the nitrogen oxide concentrations for any given unit of combustion equipment tested were found to be lower when the equipment was fired with natural gas than when fired with fuel oil.

Studies made by other investigators[5]

Table XI—Emissions from

Reference No.	Fuel Oil Burned, GPH	Fuel Oil Analysis: API Gravity	Sulfur, Wt. %	Ash, Wt. %	Flue Gas Data—Stack Conditions: Volume, SCFM[b]	Temp., °F	Orsat Analysis (Wet Basis) CO_2, Vol. %	O_2, Vol. %	CO, Vol. %	Excess Air, Vol. %
2	9	31.07	1.05	0.02	390	250	7.0	7.9	0.01	65
3	6.1	28.71	0.71	0	510	290	3.9	15.2	0.000	290
4	36.3	16.51	1.0	0	1,800	710	7.0	7.8	0.003	68
5	23.1	11.39	1.78	0.18	1,800	330	5.0	13.3	0.000	180
8	15.3	40.10	0.09	0	1,700	240	2.7	16.2	0.001	150
9	21.0	33.82	0.97	0	2,000	360	4.3	13.8	0.02	210
10	9.7	35.09	0.55	0	1,290	370	2.8	16.3	0.002	370
11	99.4	11.10	0.94	0.13	4,300	540	7.9	6.0	0.00	43
12	23.1	33.01	0.21	0.07	1,300	390	5.5	10.9	0.0024	115
13	39.6	34.87	0.29	0.01	3,100	320	4.0	13.9	0.0	220
14	85.5	32.9	0.42	0	4,200	500	6.3	9.8	0.000	94
15	160.0	8.0	3.06	0	10,600	630	6.3	10.3	0.001	110
16	80.5	12.11	0.78	0.12	4,800	220	5.9	10.7	0.0	107
17	248.0	15.09	1.39	0.04	13,100	560	6.7	9.5	0.000	92
18	57.5	13.33	1.30	0.03	3,200	580	6.4	9.6	0.0	95
19	168.0	9.30	1.94	0.03	7,800	530	8.2	8.5	0.000	73
26	5.2	33.6	0.80	0	290	820	5.4	11.1	0.002	120
27	10.0	45.1	Trace	0	230	410	9.7	3.5	0.04	21
30	20.0	45.1	Trace	0	1,200	520	3.0	15.9	0.000	373

[a] All concentrations expressed at actual stack conditions except where otherwise noted.
[b] Standard conditions are 60 degrees Fahrenheit and 14.7 PSIA.
[c] "Combustion Contaminants" are particulate matter discharged into the atmosphere from the burning
tion Control District Rules and Regulations.)

22 different power plant boiler installations showed nitrogen oxide concentrations varying from 330 to 915 parts per million on fuel oil firing and to 1350 ppm on gas firing. Nitrogen oxide results obtained on a coal-fired power plant boiler varied from a low of to a high of 1460 ppm.

Estimates of the emissions of air contaminants from the combustion of fuels by industrial sources were obtained by using an average of the emission rate factors shown in Tables XII and XIII. Information on the number of each of the various types and sizes of combustion sources operating within Los Angeles County was inadequate to allow the emission rate factors to be weighted; however, the total contaminant emission estimates obtained by using average values are believed to be sufficiently accurate.

The total annual consumption of fuel oil and natural gas by interruptible industrial sources, other than power plants and oil refineries, amounts to nearly 14 million barrels, giving an annual daily average fuel usage of approximately 38,000 equivalent barrels. The combustion of these fuels results in emissions to the atmosphere daily of approximately 65 tons of sulfur dioxide, 30 tons of nitrogen oxides and 10 tons of combustion contaminants.

Approaches to Control

There are presently within the boundaries of Los Angeles County an estimated 15,000 industrial establishments, 11 steam-electric generating power plants, seven major and nine minor oil refineries. These industrial units collectively consume an average of over 50,000 barrels of fuel oil each day. During periods of peak fuel use, the consumption of fuel oil has been as much as 100,000 barrels per day. The burning of fuel oil in these quantities results in emissions to the atmosphere of from 400 to nearly 800 tons per day of various air contaminants.

In Table XIV data are presented on the estimated daily emissions of sulfur dioxide, oxides of nitrogen and aerosols from the combustion of liquid and gaseous fuels and from other air pollution sources in Los Angeles County. It may be seen from these data that an average of 310 tons per day, or 68 per cent, of the total emissions of sulfur dioxide in Los Angeles County are from the combustion of fuels. It will also be noted that 250 tons per day of nitrogen oxides, or 36.1 per cent, are emitted from combustion sources. The combustion of fuels also releases 35 tons per day, or 40 per cent, of the total emissions of aerosols from both stationary and vehicular sources.

For purposes of comparison there are shown in Fig. 5 the relative amounts of combustion contaminants, nitrogen oxides and sulfur dioxide emitted from the burning of fuel oil and from the burning of an equivalent amount of natural gas. The annual daily average fuel consumption by interruptible industrial sources was used for this comparison. It can be seen that, if the average daily fuel requirements of all industrial sources amounting to over 120,000 barrels were supplied with fuel oil, there would be released to the atmosphere daily 600 tons of sulfur dioxide, 270 tons of nitrogen oxides and 50 tons of combustion contaminants. Were these same fuel requirements supplied by natural gas, there would be emitted a negligible amount of sulfur dioxide, 150 tons of nitrogen oxides and only five tons per day of combustion contaminants.

The largest single industrial users of both fuel oil and natural gas in Los Angeles County are the steam-electric generating power plants. In burning residual fuel oils the power plants cannot be operated so as to comply with the Rules and Regulations governing visible emissions and nuisances. Visible stack emissions, or so-called plumes, from power plant stacks are the result of the daily burning of thousands of tons of fuel oil. Depending upon weather conditions, these effluent stack plumes may extend for several miles, carrying pollution over a widespread area, or they may cause heavy concentrations of pollution at ground level adjacent to these plants. This latter effect has frequently been encountered in areas surrounding power plants and oil refineries, where heavy local concentrations have caused paint damage, damage to vegetation and troublesome soot problems.

Table XII—Emission Factors for Gas Fired Combustion Equipment

Reference No.[a]	Pounds per Equivalent Barrel of Fuel Oil[b] — Combustion Contaminants	Aldehydes (as Formaldehyde)	Oxides of Nitrogen (as NO_2)
1	0.086	0.036	0.714
2	0.353	0.059	0.588
6	0.327	0.091	0.036
7	0.067	0.017	0.333
8	0.024	0.135	0.432
9	0.023	0.042	0.225
10	0.043	0.157	0.352
11	0.033	0.191	0.200
12	0.025	0.025	0.412
13	0.021	0.059	0.774
14	0.026	0.078	0.944
15	0.927	0.415	1.34[1]
16	0.031	0.035	0.6(
17	0.069	0.042	2.167
18	0.070	0.018	0.703
19	0.042	0.125	2.125
20	0.256	0.070	1.333
21	0.046	0.046	0.738
22	0.013	0.044	0.559
23	0.041	0.094	0.406
24	0.049	0.082	0.464
25	0.382	0	0.838
27	0.038	0.024	0.223
28	0.061	0.064	0.066
29	0.043	0.053	1.158
30	0.062	0.045	0.192

[a] Numbers refer to equipment listed in Table IX.
[b] Six thousand cubic feet of natural gas is considered equivalent to one barrel of fuel oil.

d Combustion Equipment

	Air Contaminant Emissions[a] — Combustion Contaminants[c] Grains per SCF @ 12% CO_2	Pounds per Hour	Sulfur Dioxide Ppm	Pounds per Hour	Sulfur Trioxide Ppm	Pounds per Hour	Aldehydes (as Formaldehyde) Ppm	Pounds per Hour	Oxides of Nitrogen (as NO_2) Ppm	Pounds per Hour
	0.069	0.14	355	1.4	1.6	0.0080	9	0.017	47	0.13
	0.071	0.10	98.2	0.51	1.4	0.0092	5	0.013	35.8	0.13
	0.074	0.66	414	7.5	4.7	0.10	7	0.05	368	4.8
	0.11	0.68	264	5.0	3.2	0.076	9	0.08	128	1.68
	0.038	0.12	28	0.48	1.7	0.036	5	0.04	20	0.25
	0.14	0.85	11.2	2.3	5.6	0.00006	52	0.50	21	0.31
	0.10	0.26	0.2	0.0024	0	0	8	0.04	54.9	0.51
	0.064	1.55	397	17.3	0.37	0.020	8	0.2	387	12.1
	0.041	0.22	102	1.35	0.5	0.008	7	0.04	32.8	0.310
	0.142	1.25	7.1	2.24	0.0	0.0	6	0.08	14.7	0.33
	0.014	0.26	17	7.2	0	0	3	0.06	72	2.2
	0.28	13.4	700	75	6.7	1.2	4	0.2	274.9	19.8
	0.039	0.79	362	17.6	2.2	0.13	7	0.2	199	6.95
	0.0446	2.80	594	79.0	3.6	0.6	17	1.0	256	24.5
	0.060	0.87	640	21	2.2	0.091	8.5	0.12	205.9	4.3
	0.096	4.4	344	27.2	1.2	1.2	48	1.8	256	14.6
	0.073	0.081	138	0.41	2.8	0.003	11	0.015	33.7	0.065
	0.004	0.002	0	0	0	0	3.5	0.0037	27.1	0.045
	0.038	0.097	0.17	0.0021	0	0	3.4	0.020	19.8	0.17

material containing carbon in a free or combined state. (Rule 2m of the Los Angeles County Air Pollu-

The direct control of power plant emissions in Los Angeles County has been approached from three aspects: (1) treatment of the fuel; (2) boiler modification; and (3) treatment of the effluent. At the present time, there is no steam-electric generating power plant in the world known to have control equipment which is entirely satisfactory for removing any one of the contaminants produced from the burning of fuel oil. Furthermore, no practical means have as yet been devised for removing, before burning, the objectionable elements such as sulfur and other inorganic materials present in the fuel oil which give rise to these air contaminants.

Alternative Fuels and Treatment of Fuels

The importation of low sulfur content fuel oils has been proposed as an alternative to the presently used fuels. Studies have shown that the possibility of obtaining fuel oils of low sulfur and low ash contents from other major refinery areas is remote, even at premium prices.

Investigations have shown that no commercially feasible process is yet available for removal of sulfur or other inorganic materials from residual fuel oil which are responsible for the sulfur and metal oxides in the boiler effluent. Since there is no correlation of oxides of nitrogen in the boiler effluent with the concentration of nitrogen compounds in the fuel oil, a significant reduction would not result from the removal of nitrogen containing compounds in the fuel oil.

Changes in Boiler Design or Operation

Boiler design or operational changes will not effect a significant reduction in the amount of sulfur oxides emitted to the atmosphere from an oil-fired boiler, since this is a function of fuel composition. Recent investigations have demonstrated that the main factors affecting nitrogen oxide formation are furnace design and several combustion parameters. It may be possible to so modify boiler designs that nitrogen oxide formation, either when burning oil or when burning gas, may be reduced by 50 per cent.[6]

Effluent Treatment

Among the most promising control developments are those affecting the removal of contaminants, particularly sulfur oxides and particulates, from the effluent gases. For sulfur dioxide removal alone, some 50 to 60 different laboratory methods have been investigated. Of these, only a few are of any practical significance. Others are so costly that in full scale operation more energy would be required for the removal of the contaminants than could be produced by the power plant. The few remaining possibilities are still being investigated.

Table XIII—Emission Factors for Oil Fired Combustion Equipment

Reference No.[a]	Pounds per Barrel of Fuel Oil				
	Combustion Contaminants	Sulfur Dioxide	Sulfur Trioxide	Aldehydes (as Formaldehyde)	Oxides of Nitrogen (as NO_2)
2	0.672	6.552	0.042	0.084	0.605
3	0.672	3.528	0.084	0.084	0.882
4	0.756	8.694	0.126	0.042	5.552
5	1.218	9.114	0.126	0.168	3.053
8	0.378	1.302	0.084	0.126	0.685
9	1.722	4.620	0.001	1.008	0.622
10	1.134	0.011	0	0.168	2.205
11	0.672	7.308	0.084	0.084	5.112
12	0.420	2.436	0.013	0.084	0.564
13	1.344	2.394	0	0.084	0.349
14	0.126	3.528	0	0.042	1.080
15	3.528	19.608	0.336	0.042	5.198
16	0.420	9.156	0.084	0.084	3.625
17	0.462	13.356	0.084	0.168	4.147
18	0.630	15.330	0.084	0.084	3.142
19	1.092	6.804	0.294	0.462	3.650
26	0.672	3.318	0.008	0.126	0.525
27	0.008	0	0	0.016	0.189
30	0.210	0.005	0	0.042	0.357

[a] Numbers refer to equipment listed in Table IX.

Concerning the reduction of plume opacity and removal of particulate matter from flue gases, experiments have shown that the most attractive method for control is the use of electrical precipitators. The Southern California Edison Company recently completed the first full scale prototype precipitator unit at its El Segundo steam station. Experiments in which alkaline additives are injected into the flue gas stream ahead of the precipitator unit are also under way in order to determine whether a reduction of sulfur oxides can also be accomplished.

Substitution of Natural Gas for Fuel Oil

The substitution of natural gas for fuel oil would result in the elimination of particulate matter and sulfur compounds, as well as a marked reduction in oxides of nitrogen from the stack effluent. Thus, the simplest improvement that could be made to reduce air contaminants from the combustion of fuels would be to discontinue the use of fuel oil in favor of natural gas. In view of this, concerted effort is being made by the electric generating agencies to increase their allotment of natural gas supplies.

Conclusions

The demand for thermal energy in Los Angeles County is increasing at an astounding rate, and from all indications will at least double within the next eight to ten years. Essentially, all of this demand is being met with petroleum and natural gas fuels.

From an air pollution point of view, petroleum fuels are totally undesirable as an energy source because the burning of such fuels in power plants and various other industrial activities results in emissions to the atmosphere each day of hundreds of tons of air contaminants. Since this constitutes a major source of air pollution, every possible effort must be asserted to assure to this area the availability of increased supplies of natural gas.

Although considerable progress has already been made, a great deal of engi-

Table XIV—Sources and Quantities of Emissions of Sulfur Dioxide, Oxides of Nitrogen and Aerosols in Los Angeles County

Source	Contaminant Emissions, Tons per Day			Per Cent of Total		
	Oxides of Sulfur as SO_2	Oxides of Nitrogen as NO_2	Aerosols	SO_2	NO_2	Aerosols
Combustion of fuels	310	250	35	68	36.1	40
Automobiles, trucks and buses	50	435	30	11	62.9	34.5
Metallurgical industries	n	n	6	—	—	7.0
Petroleum refining	50	5	5	11	0.7	5.8
Mineral industries	n	n	4	—	—	4.6
Refuse incineration	n	2	4	—	0.3	4.6
Chemical industries	46	n	3	10	—	3.5
Total	456	692	87	100	100	100

n—Negligible (less than 0.1 ton per day).

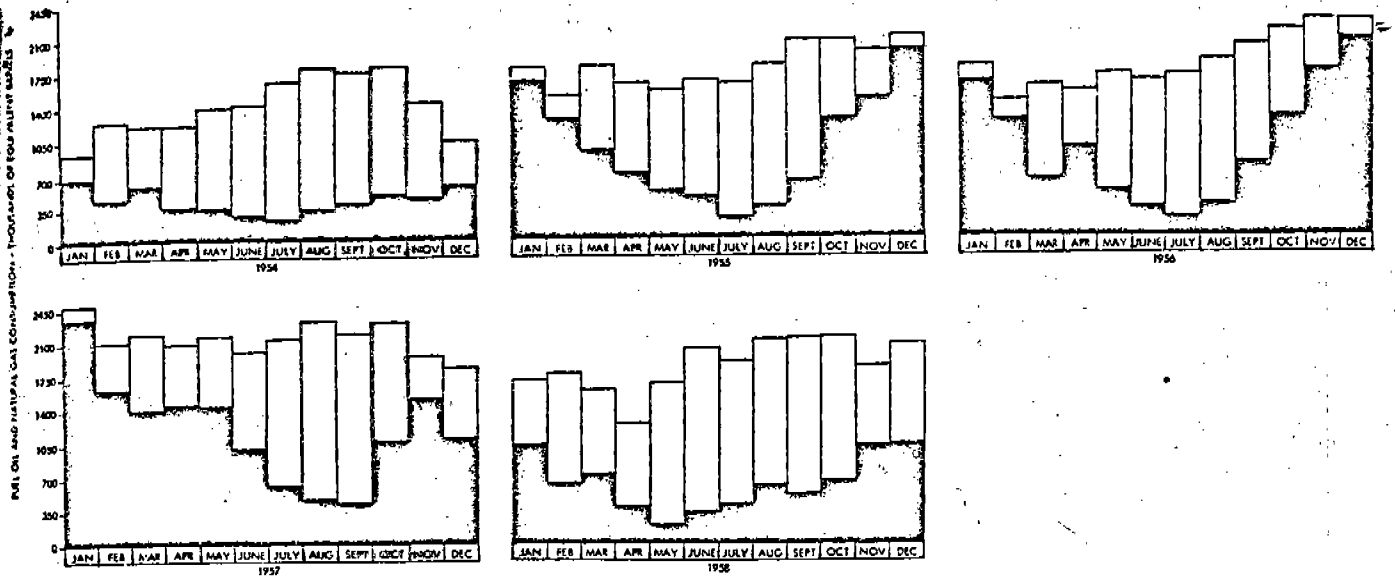

Fig. 4. Five-year summary of monthly fuel oil and natural gas consumption by power plants in Los Angeles County for 1954 through 1958.

neering research and development are still needed to render feasible the several methods proposed for controlling emissions of air contaminants from the burning of fuel oil. In the interim, it will be necessary to allocate the use of available fuels in such a way as to minimize air pollution from this source.

There is general agreement that the most desirable fuel for power generation is natural gas. It is also apparent from the forecasts of thermal energy requirements and natural gas supplies for the Los Angeles area that there will not be enough gas to meet the estimated demand, under all circumstances. The variable annual demands for natural gas by firm users will require that under certain conditions some fuel oil be burned by interruptible users. Efforts will be directed, however, toward reducing this use of fuel oil to a minimum.

Since oxides of nitrogen play an important role in the photochemical reactions occurring in the atmosphere of Los Angeles County, it is essential that steps be taken as soon as possible to determine the degree to which emissions of nitrogen oxides can be controlled. Toward this end, the APCD has initiated a Joint District, Federal, and State program with the co-operation of local power generating agencies and oil refinery industries for the purpose of obtaining the necessary information upon which future control policy can be based. Should this program be successful, a rule establishing maximum permissible limits on the emission of oxides of nitrogen from stationary sources can be expected in the foreseeable future.

Investigations will be continued to supplement the data already obtained concerning emissions from the combustion of liquid and gaseous fuels. Only when adequate information is available will the control of air contaminants from this source become a reality.

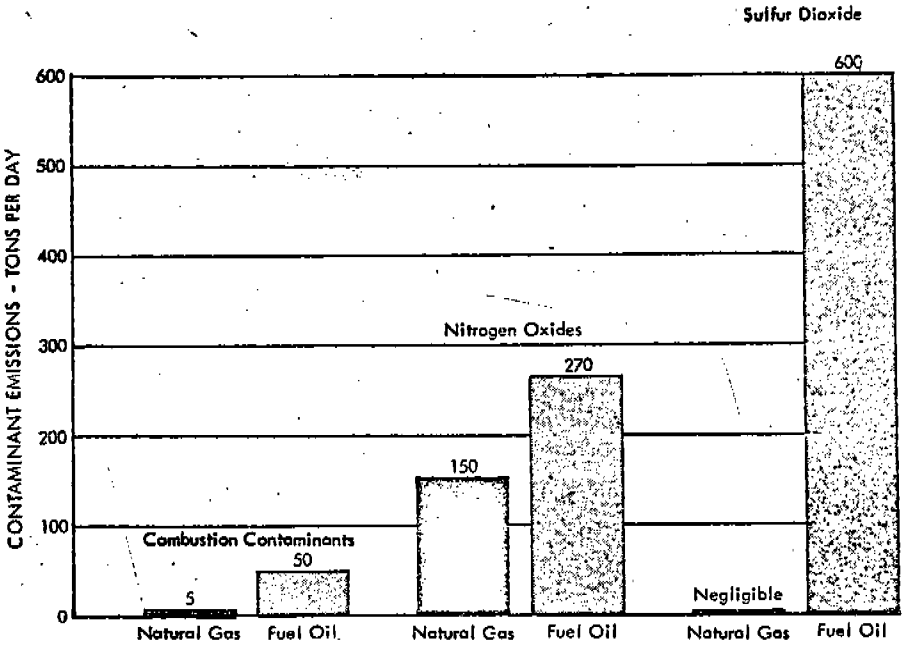

Fig. 5. Comparison of contaminant emissions from fuel oil and natural gas, based on annual daily average fuel usage for 1958 by interruptible industrial sources in Los Angeles County.

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